COMB FILTERS WITH ANALOG SHIFT REGISTERS BCCD

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Abstract

This contribution deals with the concept and circumferential structure of comb filter for video signal processing. The comb filter was implemented by means of an analog shift register CCD (BCCD). The main conclusions, including the measured frequency response characteristic and time responses of the necessary control signals, are presented. This problem has been investigated as part of the GACR project.

1. Introduction

Implementation of special comb filters [3] for TV applications, comprising analog shift registers CCD, is discussed in this paper. For combfiltering , ensuring good-quality separation of luminance and chrominance components of a composite colour signal (BOSZ) in NTSC and PAL systems, a constant time delay T is required in the basic frequency band of the video signal (approx. 0-5 MHz). However, this cannot be achieved either with the presently used ultrasonic delay lines or with the delay lines with switch capacitors (SCDL), which have lately been used in a monolithic form as components of colour TV decoders. The principle of analog combfilter is illustrated in Fig.1a.

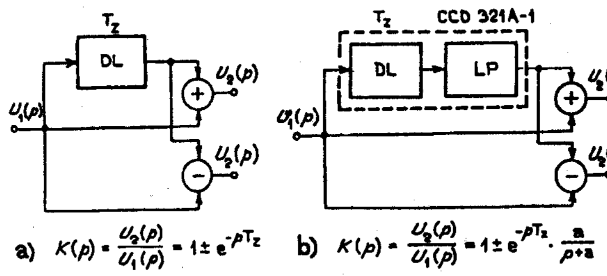

Fig.1 Principle of analog comb filter
a) with ideal delay element DL
b) with real delay line CCD

Fig.2 shows the curves for basic transmission functions K (ω), φ(ω) and τ(ω) defined for an ideal combfilter by formulas (1), (2) and (3).

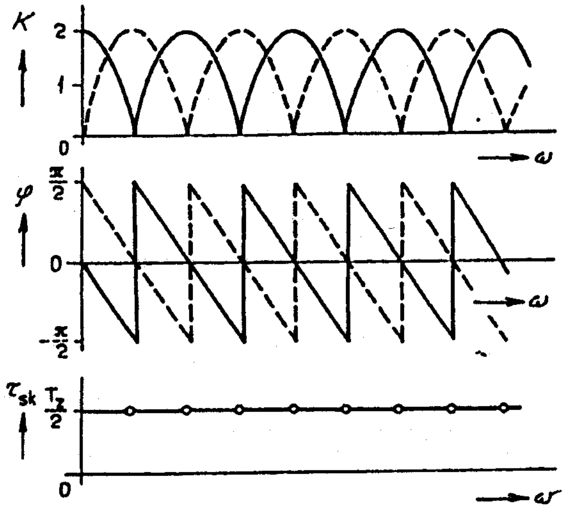

Fig.2 Curves K (ω), φ(ω) and τ(ω) for an ideal comb filter according to Fig.1a.
______ summation element
------ difference element

For the time delay element T_Z the transmission module K(ω) of the comb filter is

for summation element

$$K(\omega) = 2\left|\cos\frac{\omega T_Z}{2}\right|, \tag{1a}$$

for difference element

$$K(\omega) = 2\left|\sin\frac{\omega T_Z}{2}\right|, \tag{1b}$$

For transmission argument φ(ω) holds

$$\varphi(\omega) = \mathrm{arctg}\left(\frac{\mp \sin\omega T_Z}{1 \pm \cos\omega T_Z}\right). \tag{2}$$

In relation (2) the upper signs hold for the summation element, the lower signs for the difference element.

The group delay τ(ω) for an ideal combfilter is given by the formula

$$\tau_{sk}(\omega) = -\frac{d\varphi(\omega)}{d\omega} = -\frac{T}{2}. \tag{3}$$

For further investigation we have chosen an analog shift register (hereafter ASR) circuit CCD 321 A-1 (Fairchild) for comb filter implementation. Transmission characteristics supplied by the producer show that in the first approximation this circuit can be considered as ideal delay element connected in cascade with a 1st order low pass filter LP with a cut-off frequency $f_{up} \cong 7$ MHz (using a sampling frequency $f_s = 15$ MHz). A substitution diagram of such a configuration is in Fig.1b. The following relations can be derived for this diagram, expressing the basic transmission functions (upper signs hold for the summation element, lower signs for the difference element)

$$K(\omega) = \sqrt{\frac{a^2(1 \pm \cos \omega T_Z)^2 + (\omega \mp a \sin \omega T_Z)^2}{a^2 + \omega^2}},$$

where $a = 2\pi f_{up}$ (4)

$$\varphi(\omega) = \mathrm{arctg}\left(\frac{\mp a^2 \sin \omega T_Z \mp a\omega \cos \omega T_Z}{a^2 + \omega^2 \pm a^2 \cos \omega T_Z \mp a\omega \sin \omega T_Z}\right). \quad (5)$$

Frequency dependencies of transmission functions according to (4) and (5) for four different frequency domains are illustrated in Fig.3 (for the sake of simplicity for the summation element only).

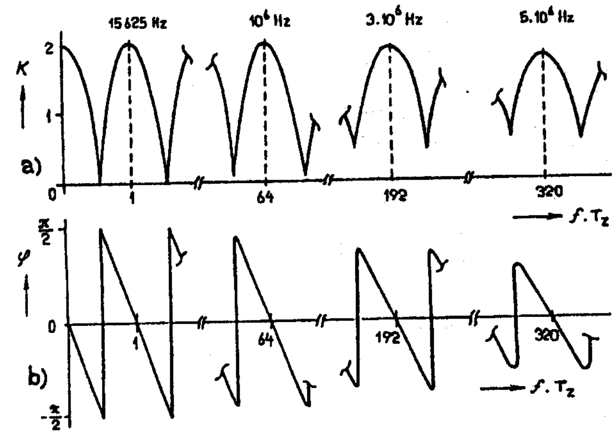

Fig.3 Theoretical curves for module a) and argument b) of combfilter transmission with a real delay element for T_z= 64 µs and a cut-off frequency equivalent to 1st order low pass filter f_{up}=7 MHz.

It is obvious from Fig.3 that the frequency dependence of transmission of the analog shift register CCD working as a delay element (related, among other things, with the sampling of signal in structure CCD) is manifested in the high frequency domain by worsening filtering effects of the comb filter - minima increase while maxima of the periodic function of transmission module decrease. The worsening linearity of the phase characteristic in the high frequency domain (over 3 MHz) leads to a greater oscillation of group delay, mainly in the area of transmission module minima.

2. Implementation of Comb filter with Periodicity fr = 15 625 Hz for the Frequency Range of Video Signals

An integrated APR CCD 321 A-1 selected for experimental verification comprises two independent ASR CCD, each with 445 memory capacitors MIS. In the described application both registers are connected in cascade (the so called serial mode [2]). To achieve the required delay τ_1= 64 µs, the frequency f_T of the shift signal ASR must be

$$f_T = f_{TA} = f_{TB} = \frac{2\,.\,445}{\tau_1} = 14,21 \text{ MHz}.$$

In this mode the Shanon-Kotelnik theorem can be fulfilled in a video signal sampling as the sampling frequency

$$f_s = f_T = 14,218 \text{ MHz} > 2.\ f_{pic.max}$$

Fig.4 shows a simplified block diagram of the comb filter. In the delay branch, the Tchebyshev filter with cut-off frequency of 5.5 MHz is connected, suppressing residual signals in CCD superimposed to the video signal (see Fig.5e). When the combfilter is set the time delay of APR CCD must be reduced by the time delay of the low pass filter (by increasing τ_{LP} the frequency f_T of the intermittent signal). By adding or subtracting video signals in the linear and in the delay branch transmission characteristics can be defined with transmission module maxima at frequencies for the summation element

$$f_{mk} = k\,.\,f_1 = k/\tau, \qquad \text{where } k = 0,1,2, \ldots\ldots \quad (6)$$

and for the difference element

$$f_{mk} = \frac{2\,.\,k -}{2\,.\,\tau_1}, \qquad \text{where } k = 1,2,3, \ldots\ldots \quad (7)$$

Illustrated in Fig.5 are time curves of video and control signals of circuit CCD 321 A-1 identical for both internal shift registers A and B. Control signals are generated in control logic CCL circuits. More details are given e.g. in [2]. Connection of the comb filter functional sample used for measurements is in Fig.6.

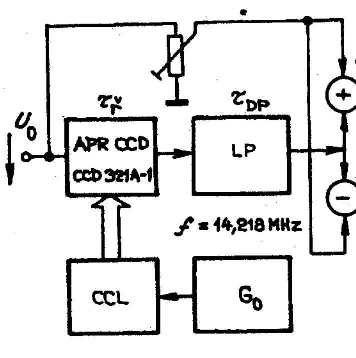

Fig.4 Block diagram of combfilter with periodicity of the characteristic f_r = 15 625 MHz.

In this stage the circuits of the control logic CCL and of the basic generator G (not drawn in detail in Fig.6) were taken from the development test board Fairchild for circuit CCD 321 A-1. In the final version they will be substituted with circuit PLD.

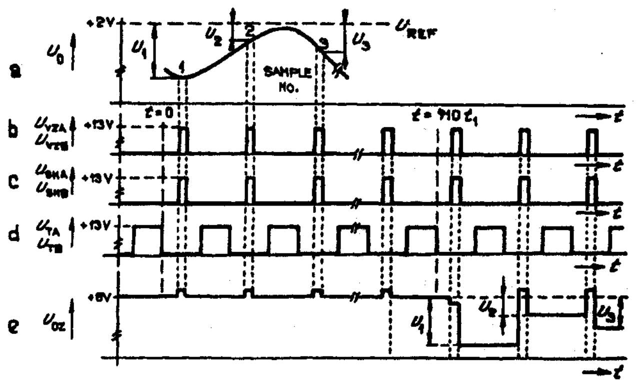

Fig.5 Time curves for video and control signals of circuit CCD 321 A-1 in serial mode
a) U_0 ...input video signal
b) U_{sA}, U_{sB} ...input sampling signals of registers A and B
c) U_{SHA}, U_{SHB} ...output sampling signals of registers A and B
d) U_{TA}, U_{TB} ...shift signals of registers A and B
e) U_{OZ} ...output delay video signal

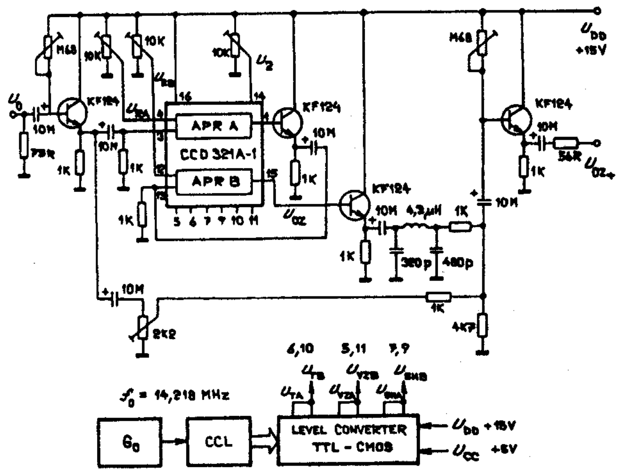

Fig.6 Diagram of comb filter functional sample for video signals with APR CCD 321 A-1 and summation element

3. Results of Measurement

Fig.7 shows dependencies of the transmission module $K(f/f_r)$ measured on the functional sample of the implemented comb filter. The dashed line shows results of measurements without the low pass filter LP and the solid line with it. Evident from the curves is the positive effect of the low pass filter in delay branch with improved rejection at points of theoretically zero transmission. The attainable minimum value of transmission at rejection points may be up to 1 MHz, approx. 2 % of the maximum transmission value, though it increases at higher frequencies. For comparison, the dotted line in Fig.7 shows the transmission module $K(f)$ theoretically derived in [1]. Leaving aside its double value following from derivation conditions, the measurement results are in very good agreement. Fig.8 also illustrates the transmission characteristic for the implemented combfilter. It is obvious that within the range 0-1 V the transmission characteristic is almost linear and is in agreement with producer's data. Measurement results confirmed assumptions and proved that the combfilter with ASR CCD can work in the frequency range of approx. 0-3 MHz.

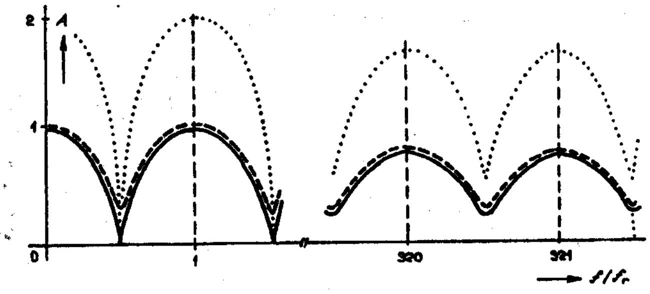

Fig.7 Transmission module of comb filter connected as in Fig. 6

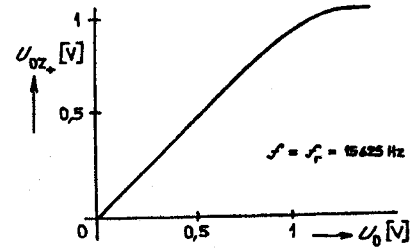

Fig.8 Measured transmission characteristic of comb filter

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